# Transversely polarized Timelike Compton Scattering using NPS/CPS (PR-12-18-005)

## Status and plans

(edited after meeting slide 12 to 15 - comments in red)

February 3, 2020 – NPS collaboration meeting

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# Outline

1) Summary of the proposal as of 2018: motivations, setup, projections

2) Recent updates on proton tracking, new solutions

3) PAC: reports, questions, main points to address

4) Status

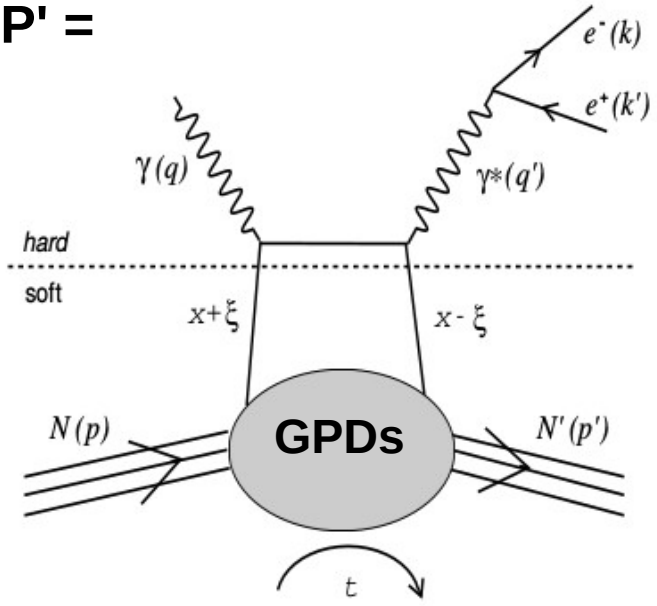
5) Plans and needs

**Context: conditionaly approved experiment in 2018 (C2), several points need to be addressed prior new submission to the PAC**

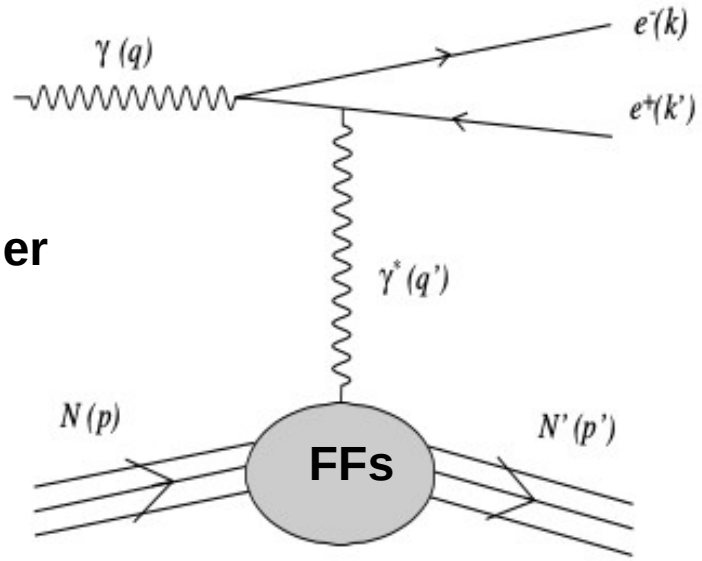
# Timelike Compton Scattering

**$\gamma P \rightarrow e^+e^- P'$ =**

**TCS**




**+ Bethe-Heitler**




Accessing Generalized Parton Distributions (GPDs)

TCS off the proton: 4 chiral-even GPDs at leading twist (H, E, $\tilde{H}$, $\tilde{E}$)

⇒ correlation between quark momentum and its transverse distribution

⇒ nucleon tomography, spin composition through sum rules…

⇒ one of the (assumed) universal quantity that describe the partonic structure of the nucleon

# Why measuring Timelike Compton Scattering off transversely polarized proton?

**Timelike Compton Scattering (TCS)**

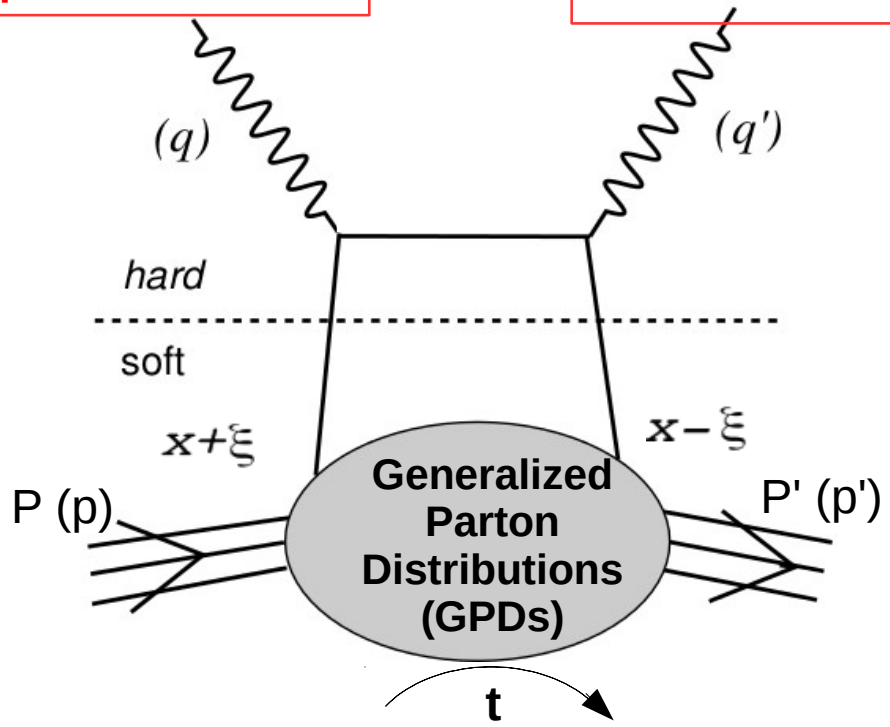
**$\gamma P \rightarrow \gamma^*(q') P' \rightarrow e^+e^- P'$**

**$q^2 = 0$ and $q'^2 > 0$**

**Deeply Virtual Compton Scattering (DVCS)**

**$e P \rightarrow \gamma^*(q) P' \rightarrow e' P' \gamma$**

**$q^2 < 0$ and $q'^2 = 0$**

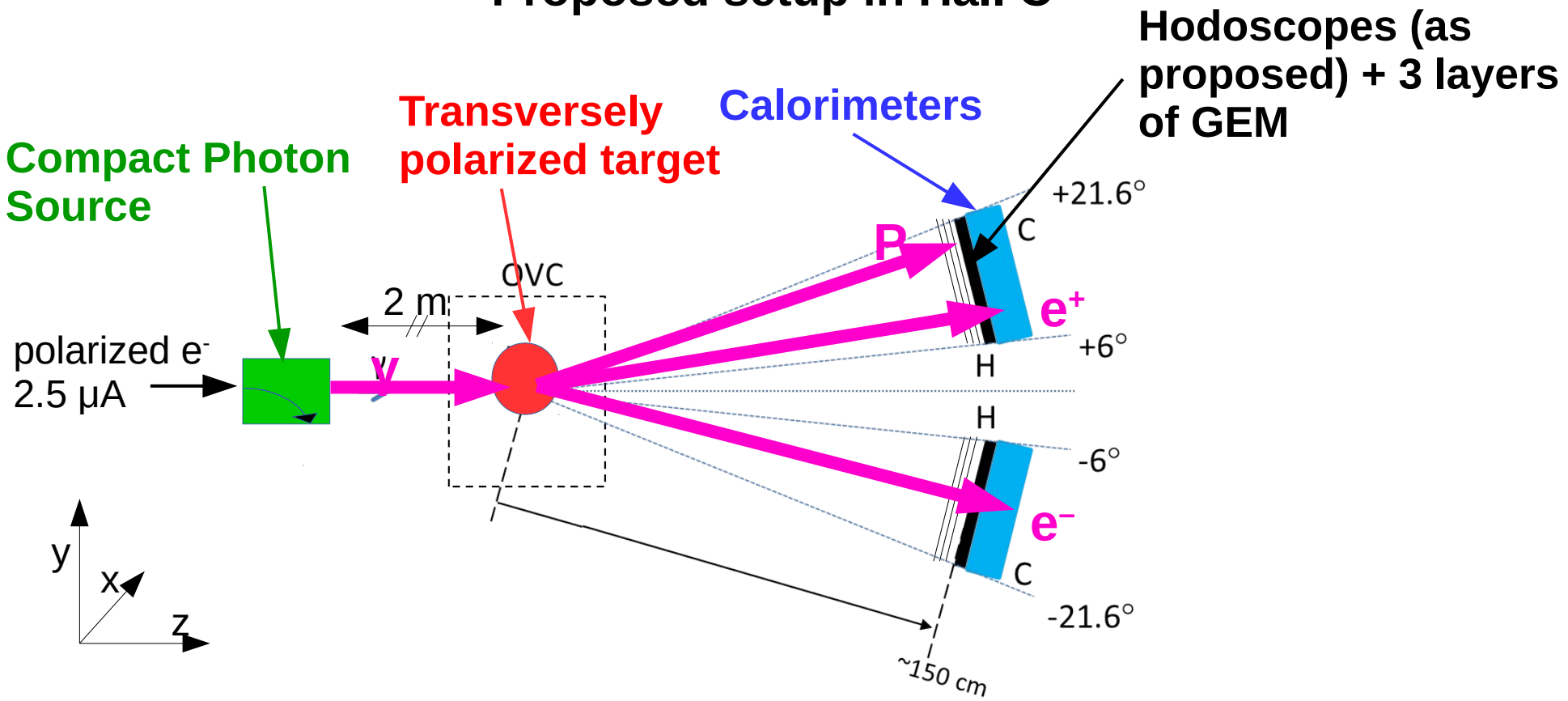



TCS and DVCS amplitudes are complex conjugate at leading twist, LO. Access same functions and same GPDs with two of the cleanest processes (only one non perturbative part)

⇒ **GPDs universality studies**, comparing GPDs extracted from DVCS and TCS independently
Need of a certain number of independent observables for extraction by fits of specific functions

⇒ Transverse spin asymmetry or cross section difference: access GPD E (Im $\mathcal{E}$): indirect access to **partons angular momenta $L^q$** (Ji sum rule)
Bring new constraint on GPDs, more difficult with DVCS due to transverse polarized target

# Proposed setup in Hall C




**Photon beam:**

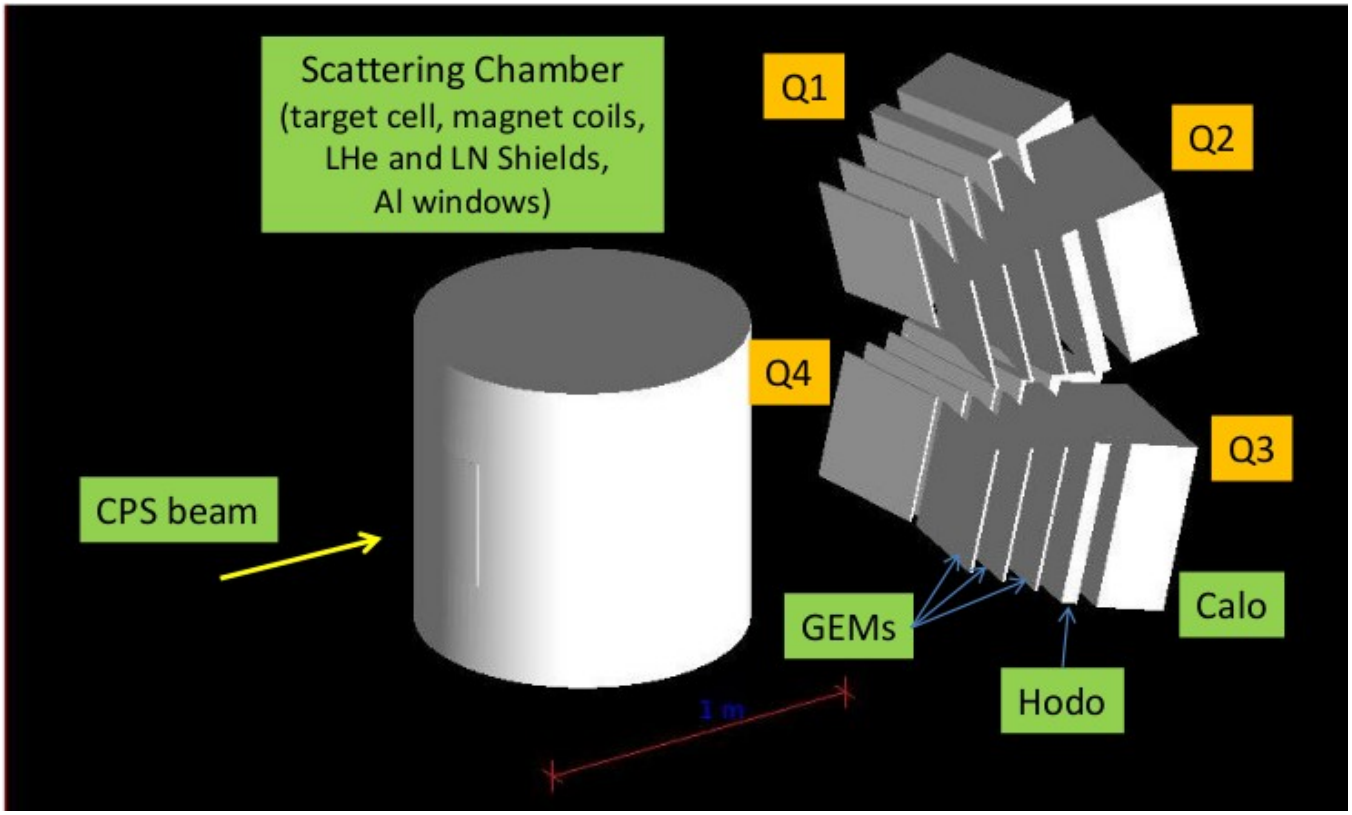
2.5 μA $e^-$ beam → 1.5 x$10^{12}$ γ/s at ~75% average circular photon polarization rate for $E_\gamma$>7.5 GeV

**Target**: $^{15}NH_3$ , acceptance ±17° horizontal, ±(6°-21°) vertical

~ 0.4 polarization dilution factor for selected events (recoil detected, subtraction of scattering off N or He)

# Proposed setup: detection of $e^+$ $e^-$ P

Updated configuration




2116 blocks total, active area 0.74 m²
Vertical aperture θ = ±1.6° (high radiation)

Calorimeters for electron pair

Proposed: hodoscopes for the proton
Now: 3 layers of GEM + hodoscopes

The beam pipe is not included in simulations currently

**Trigger, DAQ**

→ momentum thresholds : $p(e^-)+p(e^+)$ >5 GeV, 2D cuts on E and P
→ Triple coincidence and missing mass requirements

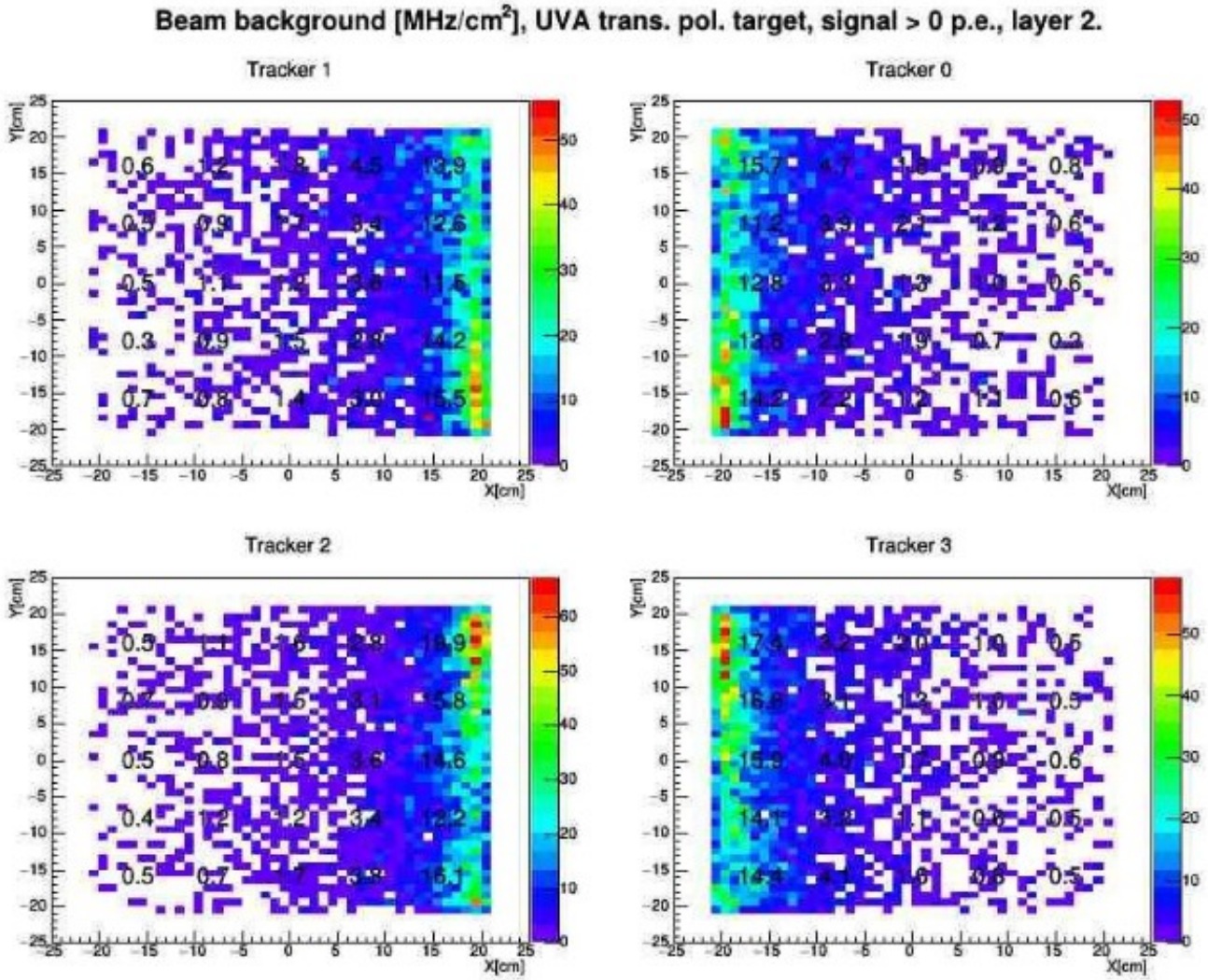
# Updates: proton tracking and background rates

from Vardan's 01/16/2020 presentation

GEM trackers
- Like COMPASS GEM detectors (F.Sauli, NIMA 805 (2016) 2-24 )
- 3 mm drift region (70% Ar, 30% $CO_2$, ρ= 1.7 mg/cm3)
- Hit signal: energy deposition in drift region

Hodo-s, 5 cm thick plastic, passive (no signal)

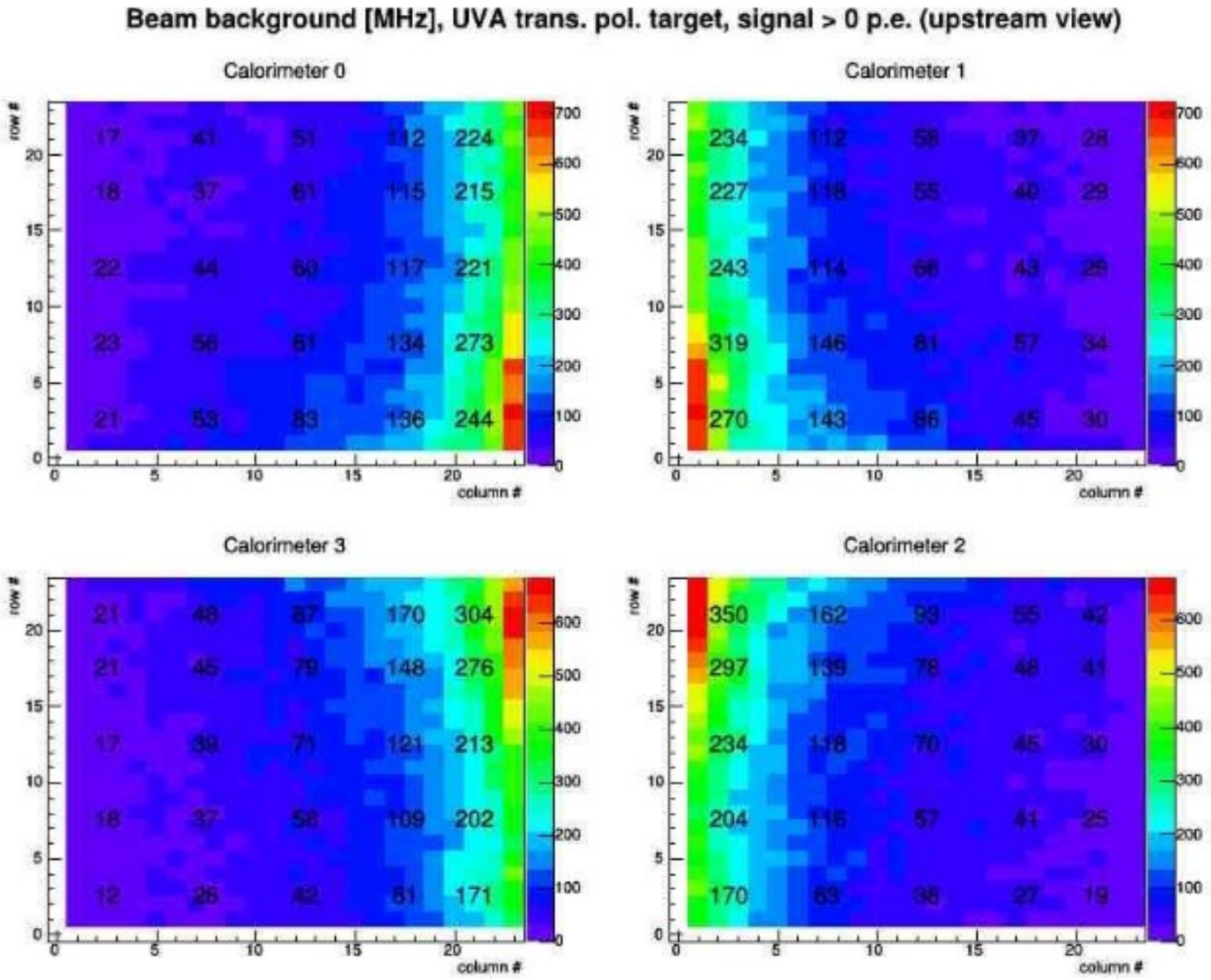
GEM Tracker rates




Rate ~1-2 MHz/cm$^2$ at centers
(can tolerate >$10^6$ Hz/mm$^2$ [PDG])
Similar pattern for layers 1 and 3

# Updates: calorimeters background rates

Calorimeter rates

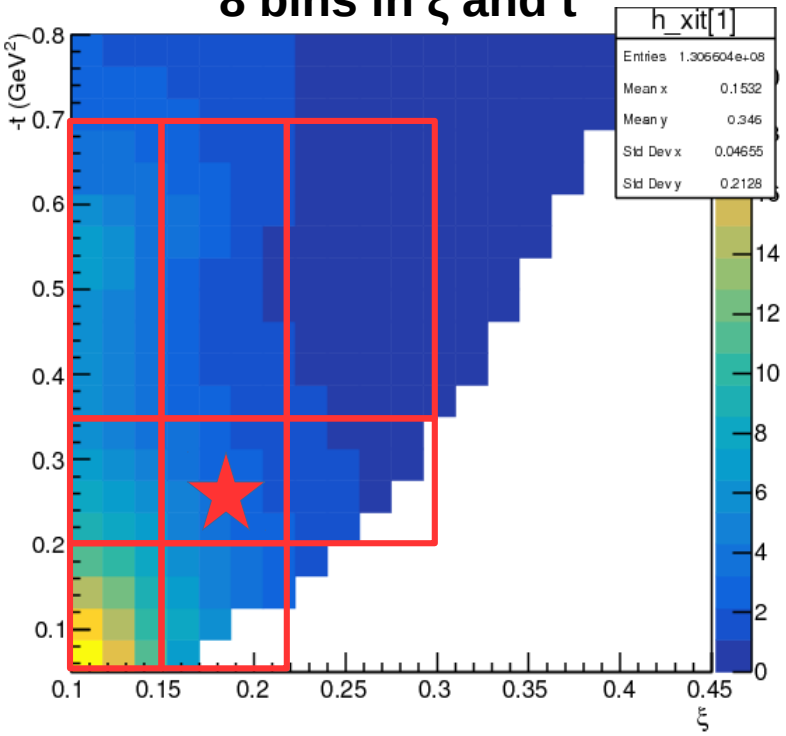



from Vardan's 01/16/2020 presentation

Rate ~60 – 80 MHz at centers

# Reconstruction and analysis ($e^+e^-P$)

## 8 bins in ξ and t




**New version of analysis**: extended phase space
-t up to 2 GeV², 5.5<Eγ<11 GeV
possible studies at lower Q'²
⇒ will not be the main of the physics, studies in progress to see what we can get out of extended range

New generator version include part of radiative corrections and some background channels

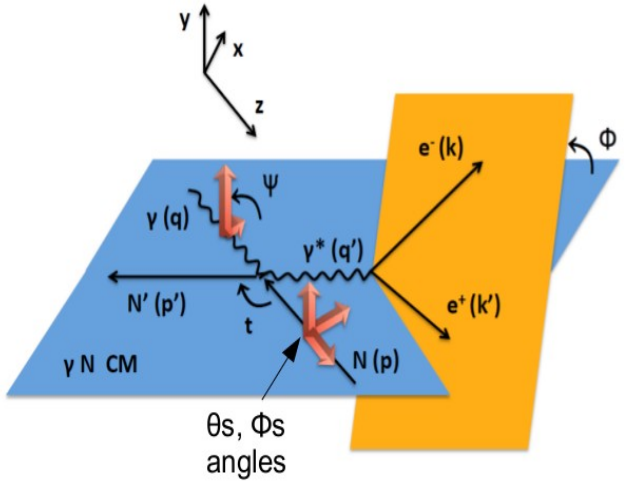
**Proposal:**
Threshold at analysis level:
$E(e^{\pm}) > 0.7$ GeV, $E(e^+ + e^-) > 5$ GeV, $p(P) > 0.1$ GeV

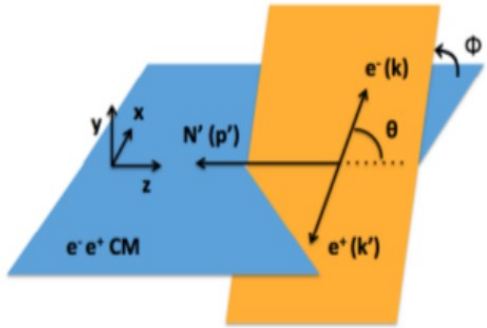
Exclusivity cuts: tagging of $e^+ e^- P$, $\Delta M^2$, $\Delta\varphi$, $\Delta P_\perp$

Angular cuts θ, φ for physics and rates:
integrated between BH peaks and/or [40°, 140°]

★ selected bin for projections
$4<Q'^2<7$ GeV², $.15<\xi<.22$, $.2<-t<.35$ GeV²

Bins: 8 ($Q'^2$, ξ, t) bins, 16 φ bins, 16 $\varphi_S$ bins,
$7.5 < E < 11$ GeV, $4<Q'^2<9$ GeV²

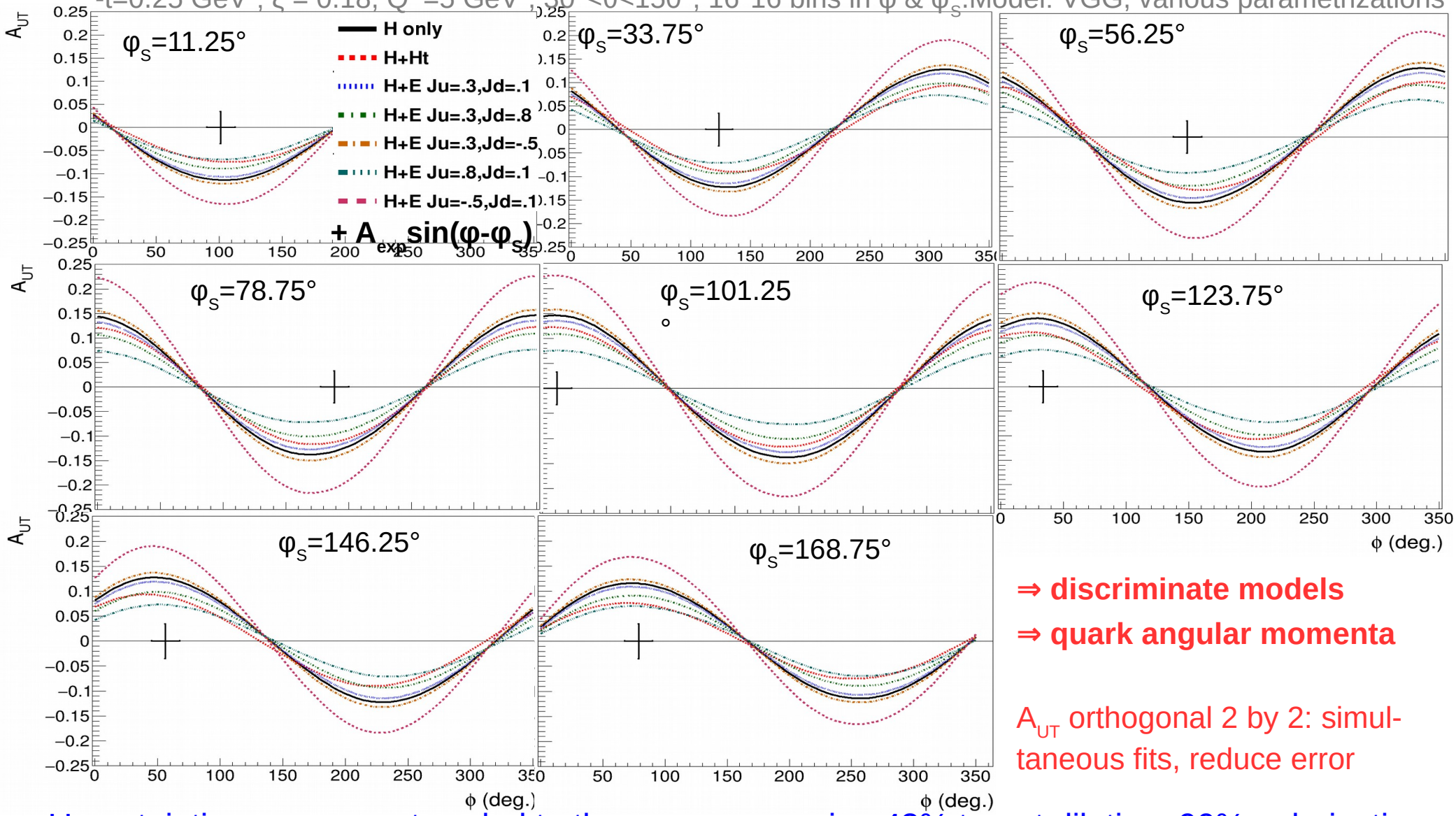


# $A_{UT}$ versus $\varphi_S$: experimental errors and model dependence

**Error bars on first moment fit $A*\sin(\varphi-\varphi_S)$ for 8 $\varphi_S$ bins and one ($\xi$, t, $Q'^2$) bin versus models**

-t=0.25 GeV²; ξ = 0.18, Q'²=5 GeV², 30°<θ<150°, 16*16 bins in φ & $\varphi_S$.Model: VGG, various parametrizations



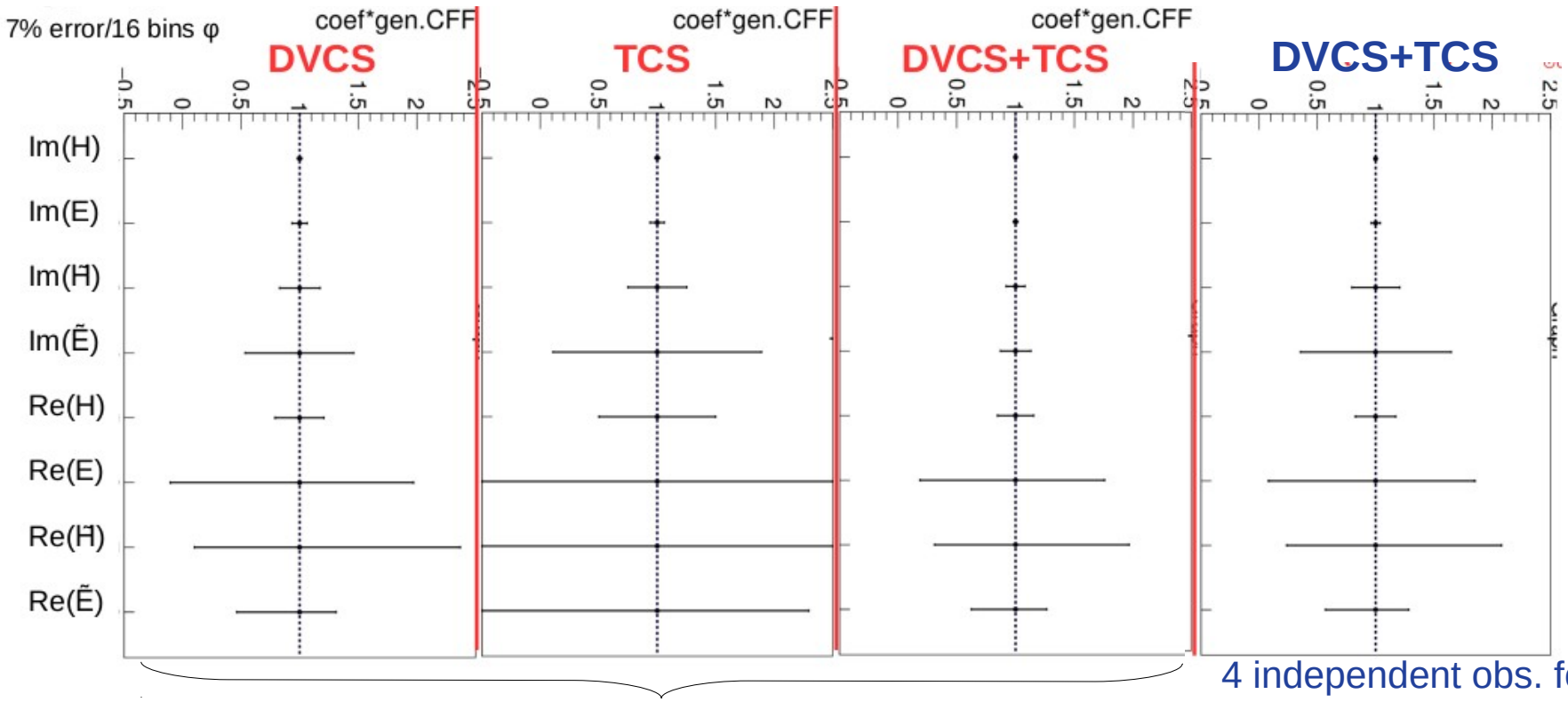

**⇒ discriminate models**

**⇒ quark angular momenta**

$A_{UT}$ orthogonal 2 by 2: simultaneous fits, reduce error

- Uncertainties on moment scaled to theory curves, using 43% target dilution, 90% polarization
- Small asymmetries case of "red" scenario using H+$\tilde{H}$ in event generator used for the proposal

# Updates: 8 parameters fits of CFFs from realistic DVCS or TCS projections




more in CPS talk of 02/04/2020

6 independent observables: unpolarized σ, beam polarized, L target (single and double A), ⊥ target

4 independent obs. for each, 6 independent in total
DVCS: unpol, beam, target L,
TCS: unpol, beam, target ⊥

- Similar sensitivities (horizontal scale) on DVCS and TCS with 6 independent observables, possibility to extract all CFFs despite under-constrained problem [compare first 2 graphs]
  NB: no experiment yet with all these observables, except for HERMES results on DVCS
- Combining first 2 graphs = 3d graph. Ideal situation, but for future
- Last graph: what could be achieved with current DVCS and this TCS experiments + extensions
  NB: assume GPDs universality and knowledge of higher twist contributions
- Impact of mass and Δ term (not full twist 3 & 4): evaluated 1% on Im(CFF), 10% on Re(CFF)

# PR 12-18-005 : TAC reports, main concerns as pointed by the reviewers

*** Scintillator hodoscopes (proton)**

comment source:

PR12-18-005_PHY

- High rates ~100 MHz, need to go down by one or two order of magnitude
  → other kind of detector? (faster, thin layers, reduce paddle size…)

ITAC

- Proton PID: method to improve (depends on detector choice)

*** Trigger**

- High rates, high random coincidence background → need estimation

ITAC/PR12-18-005_PHY

- Providing rates for the coincidence trigger

Anna Martin

*** Photon beam**

PR12-18-005_PHY

- Reduction to higher energy photon? → implied modifications at the level of CPS

*** Calorimeters**

ITAC

- Calibration and readout threshold as for PrimEx not feasible; pion rejection needs momentum determination →need to propose a method with potential setup modifications (GEM trackers...)

*** Target:**

- low acceptance at larger -t → new target with larger aperture?

PR12-18-005_PHY

- Depolarization → provide details on functionality / test results of rotating system

ITAC

- Interference between target and CPS field

ITAC

# PR 12-18-005 : theory report and PAC members concerns on analysis

comment source:

*** DAQ**

PR12-18-005_PHY

• develop software, provide schematics

*** Higher twist corrections**

PR12-18-005_TH

• impact of higher twist corrections in universality studies

→ no published results, studies exist

*** Background from N protons and exclusivity**

• full background simulations needed (π+π-, π°...)

PAC

• resolutions

→ exclusivity studies: need to add all background channels

Anna Martin

→ Measurement off N and off unpolarized NH3 additional time

us

*** Observables**

• realistic uncertainties on extracted CFFs

Marie

• 2D fits and projections to update final uncertainties on experimental projections

Anna Martin, Marie

*** Complementarity with other DVCS/TCS experiments, physics impact**

• improve physics case with broad context and what can be achieve with and without this exp.

• impact for GPDs universality and extraction

PAC

# Most urgent needs (in order) and status

| | comment source: | Status |
|---|---|---|
| **1) Solution for reduction of rates and recoil detection** | | |
| - changing configuration of hodoscopes | ITAC | Work in progress |
| - additional GEM trackers for proton PID: vertex and momenta | | Added to simulations, reduce rates to ~ 30 MHz. Need external advice |
| **2) Proton tracking in simulations** | Rolf, Anna Martin | |
| - improved tracking and magnetic field to be included in analysis, update projection (degradation of resolution/exclusivity?) | | Work in progress |
| **3) Trigger** | PR12-18-005_PHY, Anna Martin | |
| - rates estimation: random + coincidence | | To be done |
| **4) Background** | PAC, Marie | |
| - develop generator for hard exclusive π+π- and e-e+π° | | need theory input |
| **5) Target** | ITAC | |
| - study interference of magnetic field target / CPS<br>- details+results showing that it will not heat/depolarize, systematics<br>- proposed design details / update days for operations | | done, will provide references (edit) |
| **6) Theory** | PAC | |
| - impact of higher twist on universality studies, errors | | Old work need updates, ideally independent theory input |
| - include DVCS results and comparison what TCS brings | | Comparison done, will update |
| **7) DAQ** | | |
| -schematics, needed electronics | PR12-18-005_PHY | To be done |

# Most urgent needs (in order) and status

| | comment source: | Status |
|---|---|---|
| **7) Calorimeters** | | |
| - show method for calibration | ITAC | Work in progress |
| - better estimation of low energy π+π- rejection | PAC | To be done |
| **8) Background from proton resonances** | PAC | To be done ideally |
| **9) Observables** | | |
| - show 2D maps and fit result projection instead of combining 1D projections (for final uncertainty) | Anna Martin, Marie | To be done, not essential |
| **10) Updated number of days** | | |
| - days of operation: target, installation, commissioning… | ITAC, Marie | critical but will be at the end |
| **11) Improved projections, analysis…** | Marie (if time) | Mostly done |
| - radiative corrections, different models, other backgrounds… | | Mostly done but may dilute the message (may not include) |
| - enhanced phase space, double asymmetries... | | |
| **12) Additions** | | |
| - running time off unpolarized NH3 and N (background, systematics) | Anna Martin and us | Projections can be done quickly, same setup except for target part: section about N target |